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Environmental Assessment Review | Examen des évaluations environnementales

Ottawa, Ontario
K1A 0H3

August, 1980

Dear Sir/Madam:

I am pleased to forward the most recent submission(s) received by the Norman Wells Environmental Assessment Panel. As additional information becomes available, it will be made available to you.

Yours sincerely,

R.L. Greyell
Executive Secretary
Norman Wells Pipeline Project

Rec'd: Sept 11/80
Order No.:
Price: Gift
Acc. No.: R.L. Greyell

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Information

Transport Canada | Transports Canada
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X1465-17-1

August 15, 1980.

Mr. R.L. Greyell,
Executive Secretary,
Norman Wells Pipeline Project,
Environmental Assessment Review,
Department of the Environment,
Ottawa, Ontario.
K1A OH3

F.E.A.R.O.
File:
AUG 21 1980
Rec'd.

Dear Mr. Greyell:

Norman Wells Oilfield and
Pipeline Project

This is in reply to your letter of June 6, 1980, requesting comment respecting the proposed Norman Wells drilling islands and pipeline project.

From a review of the documentation provided, the Coast Guard office responsible for the Navigable Waters Protection Act has provided the following comments:

1. Ice Jams due to the Artificial Islands

   The possibility of ice jams and their effects should be studied thoroughly, because if they take place, undesirable river bed scouring and silting may occur.

2. Adequate Protection for the Artificial Islands

   The proposed side slope of the islands, and the size of the rip rap should be reviewed in the light of a possible sudden break-up of ice jams, to be certain of the stability of the island and that no excessive material would be washed into the navigation channel.

.../2

Place de Ville,
Ottawa, Ontario.
K1A ON5

3. Changes in the River Cross Section due to Possible Siltation

A combined effect of the islands and ice cover growth among the islands may increase the siltation and thus gradually change the flow distribution. Consequently, it may cause uneven scouring and silting in the navigation channel.

4. Navigation Aids and Notices

New aids and notices may be required to indicate the limits of the navigation channel and the location of pipe crossing during the construction period and after its completion.

5. Oil Spill Prevention

Adequate protection should be provided in the design in the event of unforeseen disruptions of the buried pipelines and the artificial islands, so that the pollution damages would be minimized.

6. Possible Interference to Navigation

Regulations should be provided to ensure no interference to regular navigation during the construction period.

We have also informed the Northern Transportation Company Limited of this proposal and they advise that they have transmitted their views directly to your office.

Yours sincerely,

J.-Jacques Séguin,
Director General,
Arctic Transportation Directorate.

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PRELIMINARY REPORT ON A REVIEW OF ENVIRONMENTAL IMPACT STATEMENT, RELATING TO NORMAN WELLS OILFIELD EXPANSION AND PIPELINE PROJECT

Submitted to

FEDERAL ENVIRONMENTAL ASSESSMENT REVIEW OFFICE

August 20, 1980

PETER J. WILLIAMS & ASSOCIATES LTD.

983 Cromwell Drive
Ottawa, Ontario
KIV 6K3

41423

PREFACE

This is a preliminary report of a review of the Environmental Impact Statement submitted for the Norman Wells Oilfield Expansion and Pipeline Project, to the Federal Environmental Assessment Review Office (FEARO). The review has included the study of supporting documents as listed, also supplied through that office. A request was also made to FEARO, for transmittal to the proponents, for further documentation relating to various geotechnical aspects. The reply was received that this further documentation would not be available before the technical hearings in late August.

This report was prepared by Peter J. Williams & Associates Ltd., and is based on the work of a team consisting of Dr. Williams, Dr. M.W. Smith, Dr. T.P. Wilkinson, and Dr. J.K. Torrance of the Geotechnical Science Laboratories, Department of Geography, Carleton University. Advice has also been received from Professor W.H. Bowes of the Faculty of Engineering. The geotechnical aspects of the Environmental Impact Statement, particularly the geotechnical and geothermal problems arising from the presence of discontinuous permafrost were the main subject of our review. Brief remarks on artificial islands and associated constructions to be located in the Mackenzie River are included.

for Peter J. Williams & Associates Ltd

August 20, 1980

Peter J. Williams

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1. NORMAN WELLS OILFIELD EXPANSION AND PIPELINE PROJECT

There are two distinct parts to this project. Oil wells are to be placed in artificial islands in the (present) bed of the Mackenzie River, and also on Goose and Bear Islands. The new and existing wells at these locations will be linked by pipelines leading to a central processing plant at Norman Wells on the mainland. This collectively constitutes the "oilfield expansion".

It is also proposed that the increased production at Norman Wells be carried in a pipeline, to be constructed from Norman Wells to Zama, Alberta - this constitutes the "Norman Wells Pipeline".

2. NORMAN WELLS OIL PIPELINE

Oil pipelines in permafrost regions involve construction features distinct from those appropriate in temperate lands. The only major pipeline in the North American permafrost regions is the large diameter (42 inch), trans-Alaska oil pipeline. The Environmental Impact Statement (EIS) for the Norman Wells line contains no reference in detail to previous experience with northern pipelines. From a geotechnical point of view, the important feature of the trans-Alaska oil line was the necessity to raise half of the length of the line above ground in order to overcome problems (which became apparent during construction planning) arising from buried ground ice.

The present proposal differs from the trans-Alaska line in a number of important respects. The Alaskan oil was necessarily maintained warm,

while the fluid properties of the Norman Wells oil are such that it can move through the pipe at temperatures around $0^{o}C$. This reduces the problem of thawing of ground ice. The Norman Wells line is only 324 mm. diameter compared with 1067 mm. of the trans-Alaska line, and, as a general rule, small-diameter pipes are less susceptible to rupture. They therefore present fewer geotechnical difficulties. On the other hand, there is buried ground ice over a 'significant' percentage of the proposed route, and the entire length of the Norman Wells line lies within the discontinuous permafrost zone where the ground is particularly prone to freezing, or thawing, as a result of natural or man-imposed changes. Furthermore it is proposed to bury the pipe for essentially the entire 866 km. In the case of the trans-Alaska line, parts of the buried sections involved elaborate arrangements to avoid thawing and ground settlements subsequent upon the disturbance due to construction procedures and the pipe itself. No such special procedures are described in the EIS for the Norman Wells line.

From the geotechnical point of view, in reviewing the EIS, a key question is whether the smaller diameter of the pipe and the low temperature of the oil, permit the relatively simple and uniform designs envisaged; both the integrity of the pipe and the avoidance of undue disturbance of the natural environment must be assured. Certainly such assurance is not immediately available. The EIS and the associated documents we have reviewed, appear to dismiss inherent difficulties lightly, and details of special designs or construction procedures are minimal.

3. DESIGN CONSIDERATIONS FOR FROST HEAVE AND THAW SETTLEMENT

Modifications of pipeline foundations in areas of discontinuous permafrost, compared with conventional designs, must be based on a knowledge of the extent to which the characteristic soil thawing or freezing phenomena might occur. There are two, essentially distinct, considerations. Firstly, it is necessary to prepare designs for the worst possible case, and to establish that these designs will ensure the integrity of the pipe. Secondly, it is necessary to establish the extent to which design modifications will be required to accommodate lesser degrees of potential frost heave or thaw settlement, and to establish that the greater length of pipe affected by these less-severe modifications will also not unduly disturb the natural environment. These two aspects will be considered separately.

Maximum thaw settlement: Of the items submitted to us, only item (6)* (an Appendix to Vol. 3a of the E I S) considers this in any detail. Part 3: Geothermal Analysis, involves a brief text and several diagrams, which show by graphs the depths of thaw expected around a pipe, and under various disturbed surfaces. Information in the diagrams is presumably used to draw the general conclusion that, in most of the terrain units along the route, the amount of thaw settlement will be less than 0.8 metres, but occasionally up to 1.2 metres ((6) p. 21). It is commented that additional field and laboratory work is required ((6) p. 21).

The oil is planned to enter the pipe at a temperature within a degree or two of the mean ground temperature, and in the EIS, Vols. 1 and III,

---

* bracketed numbers refer to documents examined - see list at end of this re

(1), (3), it is implied that the temperature of the oil will generally be that of the immediately surrounding ground. Nevertheless it is recognized (6) that thaw settlement or frost heave will occur at certain transitions between zones of different temperature. It is noted (6) that there are natural changes of ground temperature along the length of the pipe. In fact, these will be frequent, as ground temperatures vary with vegetation type and other surface characteristics. Passing from a region of one temperature to another the flowing oil will either warm or cool the ground. On page 16 of (6) there are several unclear statements such as

> "studies carried out ..... showed that the temperature of the pipeline warmed up to warm surrounding unfrozen ground temperatures quickly but would drop down to colder permafrost temperatures slowly as the pipeline passed through long sections of unfrozen and frozen ground respectively. This means that the temperature of the pipeline would always be close to the ambient ground temperatures".

No explanation is given for the first statement, and no definition of 'close', nor any justification for the second statement. However, diagrams (figures III 2.3 to III 2.6) based on calculations which are not reported in detail, show maximum thaw depths below the pipe of one, to almost five, metres in 13 years.

It is certainly difficult to make precise predictions of depth of thaw, and the innumerable changes of ground surface conditions, soil conditions and natural thermal regime make the problem very complex. Thus considerable variation is to be expected in permafrost occurring at intervals over the 900 km. of the line. Figure III 2.1 in (6) shows data derived from several authors (although full referencing is not given)

showing depths of thaw under various disturbed surfaces. Although aspects of this diagram are unclear the depths of thaw over time periods of up to twenty-eight years have been observed to be as great as six or seven metres. Predicted depths could be in excess of 9 m. Brevity of discussion in (6) suggests that the number of situations leading to extreme cases has not been fully considered, and there are certain anomalies in the figures. For example the maximum depth of thaw under the pipe when placed in degrading permafrost in the southern-most region (region 16) is predicted to be substantially greater than the northern region (region 14) ((6), table III 2.1). Yet the existence of degrading permafrost is itself indicative of a certain thermal regime, and ground temperatures near to zero, regardless of latitude. The difference in predicted thaw depths therefore needs further explanation.

The possible combinations of circumstances promoting maximum depth of thaw, such as natural conditions promoting active degradation (including eventual climatic change) together with changes of the natural ground surface by construction procedures, and the presence of the pipe itself would produce much greater thaw than one of these circumstances alone. Table III 2.1 gives the largest thaw depth below the pipe as 5.1 m, after 20 years, although there is no justification given for this being a maximum field value.

The amount of settlement occurring due to thaw depends on the amount of ice in the ground. Indeed it would appear that the maximum settlement would occur when a body of ice is present such that the thawing involves ice alone. The settlement will then be equivalent to

the thaw depth (the thaw depth for this case will be somewhat less than for interbedded soil and ice because of the large latent heat of fusion of the ice). The possibility is high of bodies of ice of a metre thickness occurring at least occasionally. It is not stated clearly in (6) what ice content was used as the basis of the calculation of the thaw settlement values quoted, but it is unrealistic to suppose that thaw settlements will not exceed the suggested 1.2 metres ((6) p. 21), which would represent only a 25% excess ice content (that ice responsible for settlement) in a 5 metre thawed layer.

In summary the discussion of the geothermal analysis is so brief, lacking consideration of several important elements, that no great reliance can be placed on the thaw settlement figures quoted. No details are given of the calculation methods. It may be that ultimately much more precise figures will be required. This could be the case if the pipe stresses resulting from differential thaw settlement were such as to threaten to rupture the pipe. Nowhere in the EIS or documents we have examined, is there any demonstration of the magnitude of settlements which could in fact be accommodated by the pipe without distress.

It is important to consider what thaw settlements of even one metre imply. They may be infilled as they develop but this would require transport of fill materials and personnel to the site with considerable disturbance to the terrain. Alternatively, the settlement will develop into irregularly shaped pits and depressions, a metre deep and commonly water-filled, adjacent to the pipe. The depressions, or small elongate ponds will generally extend a metre or two laterally on

each side of the pipe. Occasionally the presence of the standing water will itself cause a lateral extension of the depression and a continuing deepening. It is a well known phenomenon in permafrost regions that water bodies can promote thawing of permafrost. Where ice-rich permafrost has a temperature very near to thawing point, quite large ponds develop in this way. Where the ground is sloping however, there will be a tendency for the settlements to coalesce producing a watercourse beside the pipe (which could then be exposed at intervals). These various phenomena will develop with time, and will tend to continue to do so after use of the pipe is discontinued. The one page devoted to 'Abandonment' in the EIS ((4), p.A5-18), does not discuss this tendency, and the statement "eventually even the minor visual evidence of the pipeline would disappear" is absurd.

The extent to which the effects noted will occur (and may be exaggerated where thaw settlement exceeds the 1.2 m. predicted) will depend on the frequency of ground ice, the temperature of the ground and other circumstances. The predictability is considered in section 3, below.

Frost-heave: A maximum freezing of about one metre of the soil beneath the pipe is predicted ((6) p. 19), with melting of this each summer. The freezing is ascribed to the cooling effect of the oil, when itself cooled following passage through a section of pipe in 'cold' permafrost. This is a further contradiction of the repeated statements in the EIS volumes that the oil will have the ambient ground temperature. It is concluded that frost heave will not be a problem however ((6) p. 23).

The possibility of a racheting of the pipe by seasonal frost heave (a mechanism similar to that by which large boulders may be lifted from the ground) is not discussed. It might also have been noted that natural seasonal frost may well penetrate to greater depths than the pipe, in any case. In addition, for initially unfrozen ground with temperature near to $0^{o}C$, it is possible that new permafrost will be formed around the pipe with the possibility of longer-term slow frost heave with the development of high frost heave pressures. The demonstrated inconstancy of climate ('climatic change') means that some aggradation of permafrost (with frost-heave), or degradation of permafrost (with thaw settlement) will occur in any case. It would certainly appear with the relatively high oil temperatures envisaged there should be no insuperable frost heave problem, but the extent to which insulation or other procedures might be desirable is not discussed in detail.

In fact there is no detailed discussion anywhere in the EIS or other documents of the engineering designs to accommodate either the maximum possible thaw settlement, or the eventual frost heave.

Slopes: The problems associated with ground freezing or thawing are particularly evident on slopes. Several types of landslides occur as the result of poor drainage, and lack of soil cohesion, associated with the thawing of seasonally frozen ground and permafrost. Knowledge of these, and of geotechnical procedures to circumvent their effects, is becoming established. However, prediction of their occurrence, and size, is made difficult by the uncertainties noted above, in the prediction of rates of thaw for specific locations.

There is a category of slow soil movements, described as solifluction, and which may include a slow creep of 'warm' permafrost, which is less understood. These phenomena are not discussed in the EIS or associated documents.

The erosion of soil by running water, often leading to gullying, is also particularly marked in association with thaw settlement. This is referred to in four pages in (6) which represent the extent of the discussion of mechanical aspects of slope stability except for four figures in Vol. 3b (3), in the documents submitted to us. It is stated ((6) p. 23) "most of the slopes that could have the potential for special backfill requirements have been identified on the Geotechnical Maps in Volume IV". They do not appear on the maps submitted to us, which, in fact, are in Vol. 3c (5).

The suggested remedial measures briefly described ((6) p. 22, and (3) figs. 2.3-4, 2.3-12, 2.3-13) mainly involve placing of granular material adjacent to the pipe. There is no discussion of the procedure in relation to the different hydrological, soil, and other conditions occurring on slopes. In fact, in some circumstances such granular fill would serve to channel sub-surface water flow and thus create greater problems including increased thaw. There are several references to designs which are not yet developed.

4. LENGTH OF PIPELINE AFFECTED

While the extreme cases of thaw settlement or frost heave represent a threat to the integrity of the pipe itself, the length of pipe exposed

to varying but lesser degrees of settlement or heave is important with respect to disturbance of terrain. In the EIS ((4) page 4-13) it is stated

> "examination of the boreholes identified on the geotechnical maps clearly shows that a great majority of the holes drilled near the selected prime pipeline route have low amounts of ice present. The areas of potentially sensitive terrain along the route have been identified on the geotechnical maps as those soils which may contain medium or high ice contents".

The geotechnical maps, EIS volume 3C (5) (- there appears to be discrepancies of volume numbering, volume 4 being cited in Appendix I (6)) do not clearly delineate such terrain. On the contrary the map legends with the classification of intervals along the pipe by a system of numbers, give the impression that over long stretches medium to high ice contents are common, and that active 'degradation' (active natural or man-induced thaw settlement) is also frequent. For example the geotechnical map of the penultimate southern stretch (south of Fort Simpson) shows that about 60% of the terrain is described as category 1,3,7 or 8 (interspersed with 6, and 9). The legend explains that medium to high ice contents are present in materials 1,3,7 and 8 and low to medium ice contents in materials 6 and 9. The contradictory and incomplete nature of the information (for example whether the boreholes were essentially at randomly selected sites, or possibly located as part of a search for fill materials) make it impossible to assess accurately the frequency of transitions between frozen and unfrozen ground and the frequency of occurrence of excess ice and associated thaw settlement

problems. The EIS and Appendix I (6) frequently have qualitative expressions such as 'high', 'medium' or 'low' ice contents, without definition of how much ice corresponds to each category. Permafrost is described as 'intermittent' without there being any indication as to whether transitions from frozen to unfrozen ground occur every few hundred metres, or kilometres, or tens of kilometres. 'Some to considerable degradation of the permafrost' is a very significant observation, requiring elaboration. Thus it is impossible to gain a conception of the length over which there would be need for other than conventional construction, or for special maintenance procedures. Many kilometres may exhibit terrain disturbance of importance, but insufficient to necessitate measures to ensure the integrity of the pipe. Thus this is a problem of environmental impact, rather than of the satisfactory operation of the pipe.

5. GEOTECHNICAL DESIGN RELATIVE TO THAW SETTLEMENT OR FROST HEAVE

Volume 1 of the EIS: Overview Summary, (1), contains the statement (section 2.0) " .... permafrost is not expected to be a major problem and conventional methods of construction for buried pipelines can be used". Appendix I and the geotechnical maps demonstrate that the major considerations of a geotechnical nature and with respect to environmental impact, in the case of this pipeline relate on the contrary to the requirement for non-conventional pipeline construction. Design modifications to accommodate thaw settlement or frost heave are, in the documents we have

seen, referred to extremely briefly. Consideration of the use of "padding" (EIS Vol. 3a, p. 2-2) to permit displacements of the pipe without attendant excessive stress, should presumably include detailed analyses of stress and deformation in both the pipe and frozen soil materials. While the small diameter of the pipe compared with the trans-Alaska pipeline is obviously advantageous, the mere fact that it has been necessary to consider padding (which is the provision of softer or compressible materials to accommodate pipe deformation) demonstrates that the possibility of pipe rupture due to thaw settlement or frost heave is recognized. The difficulties of analysis already demonstrated elsewhere for large-diameter pipelines, especially for transitions from frozen to unfrozen ground, emphasize the need for further information. There is no indication that the results of the geothermal analysis described in Appendix I (6) have been involved in any direct way in the pipeline design. We note that on the Construction Plan Maps, EIS Vol. 3c, (5), variations in pipe wall thickness are shown. However these do not appear to relate to the variations in the likelihood of thaw settlement or frost-heave problems. Revegetation of exposed surfaces is discussed in the EIS, but in the context of restoration of the natural condition. There is no indication that the importance of vegetation and the nature of the surface, in modifying the energy exchange, has been considered in relation to the geothermal analyses of thaw settlement.

Borrow requirements are noted for various purposes ((6) p. 27) but these do not include filling of thaw settlements adjacent to the pipe. This requirement, of course, would be spread over many years.

The amount will depend on the, as yet unpredicted, extent of thaw settlement.

None of the documents submitted to us refer in any way to placing the pipe above ground. This would be the most obvious way of avoiding thaw settlement or frost heave effects due to the pipe itself, or indeed of avoiding effects on the pipe if settlements or heaves occurred from natural causes. Furthermore the relatively small diameter of the pipe means that this solution would be less costly than in the case of the Trans-Alaska pipe. It is hard to believe that the above-ground mode has been totally rejected. If not, then discussion of this mode and possible frequency of its use should surely appear in the EIS.

River crossings: The pipeline route crosses a number of rivers which are tributaries of the Mackenzie. These river crossings do not represent a fundamental geotechnical problem for the pipeline. Nevertheless both the construction procedures, and the continuing changes in ground or river conditions during the life of the pipeline, are a possible source of major disturbance to the environment. It is made clear (e.g. (3), p. 2-56) that detailed designs are, in general, not yet prepared. Consequently there is an absence of information, providing assurance that appropriate procedures to limit environmental impact will be followed. Inevitably this constitutes a serious deficiency in an environmental impact statement.

6. OILFIELD EXPANSION

Islands are planned to be constructed in the Mackenzie River,

where some of the wells will be located. Pipelines will be laid between the islands and across the Mackenzie to the mainland shore. These represent engineering operations of considerable complexity; they are of a kind largely outside our experience. The following comments therefore refer only to certain general points, and to details relating to fluvial processes which have been noted in the documents submitted to us.

Experience has been gained over a longer period of time in the case of river engineering in cold regions and is presumably more substantial than for pipeline construction in permafrost. There is probably not a basic lack of knowledge, relative to northern river engineering, comparable to that relating to thaw settlement and especially frost heave. Nevertheless the following discrepancies or deficiencies are noted with respect to the material we have examined (items (2), and (7) to (14) inclusive). It is stated in the EIS (2) that 26 ha of channel bottom will be lost to benthic production when the islands are constructed. More important would seem to be the approximately 100 ha that can be calculated as being dredged to provide the necessary 2×10^6 m^3 of sand if this were taken from the river bed, as proposed in (8), p. 25. This figure does not appear in the EIS or associated documents submitted to us.

There is disagreement between two documents (7) and (8) concerning the suitability of material for construction of the islands. According to (7), p. 18, alluvial materials are not likely to be a satisfactory fill material. Document (8) however states (section 2.6) that the sand can be used as fill material although "more data is required regarding grain sizes and available quantities." There is inconsistency in the EIS (2)

over the extent of scour and silting of the river bed. Statements range from (Section 5.3.1) " ... bed materials are likely resistant to scouring" to (Section 5.5.1) " ... extensive siltation and scour occurs." Such uncertainties will presumably have to be resolved before the impact of dredging operations can be assessed fully. Estimates of suspended load (sediments) vary greatly ((9) p. 18 and (8), p. 25).

In item (9) it is stated that the reduced hydraulic cross section (associated with construction of the islands) may induce 2 m of scour. The EIS Vol. 2 (2), Section 6.1.2, however, refers to an estimated 5.4 m possible maximum scour depth, if ice jams occur. This depth exceeds the burial depth, in general, of the pipe to the shore, which therefore might be exposed by scour. Whether 5.4 m is reached would depend on the "erodibility of the clay bottom materials" of which "preliminary estimates ... should be available by late May 1980".

The possible extent and effects of ice jams associated with the artificial islands are not resolved. Alternative designs to accommodate the effects of jams are suggested by one consultant ((10) p. 2). The EIS (2) refers (Section 6.1.2) to studies and reports on ice jamming which will be undertaken "during and after construction" and "will rely heavily on the opinions of qualified specialists and local residents". It is clear that there were many questions concerning the effect of ice jams, and the consequences of the construction of the artificial islands on the river regime, which remained at the time of preparation

of the EIS.

The problems arising from discontinuous permafrost have already been discussed in relation to the main pipeline, extending from Norman Wells to Zama. Pipelines associated with the oilfield itself are, of course, exposed to similar problems. Heating cables are planned, to allow maintenance of fluid temperature and prevent freeze-ups if production stops, and an above-ground utilidor system is proposed (11). No statement concerning temperatures of the fluids within the pipelines is found, but presumably these are, in general, substantially above ambient. No details are given in the EIS of design calculations relative to the use of insulation which is proposed for all land portions to minimize thaw and settlement. Although the length of pipeline associated with the oilfield is only some 13 km. ((11) p. 45), "thaw settlement of the pipeline is a concern" ((11) p. 39) with "observed excess ice contents up to 30%". Furthermore,

> "Frost heave .... is a potential problem on Bear and Goose Islands. .... The pipeline should be buried to a depth of at least 2.5 m. in these soils". ((11) p. 40).

There is no discussion of the reasons for these statements.

It is evident therefore, that in addition to the problems discussed earlier in this report, in relation to the main pipeline, the oilfield lines will involve certain additional specific considerations. The EIS and associated documents in their present form, lacking any detailed description of designs or of design calculations for geothermal considerations, cannot provide assurance of due regard to environmental impact.

CONCLUSIONS

1. Field investigations have shown that the pipeline from Norman Wells passes entirely through the discontinuous permafrost region, where the ground may have substantial ice contents. This requires measures to avoid probable widespread thaw settlements, and frost-heave effects. The greatest problems would follow from a combination of natural circumstances with the disturbance of the ground by the construction and operation of the buried pipe. There is no indication in the EIS that such problems have been considered directly in the design of the line.
2. The maximum depth of differential thaw settlement is suggested as little more than one metre. There is no justification for such a figure. In the absence of backfilling or other procedures, water-filled depressions of up to several times this depth can be expected, on occasion, adjacent to the pipe.
3. The extent of terrain disturbance including the formation of water courses and erosion, together with the effects of pipeline maintenance or rectification procedures, are understated in the EIS. The EIS and associated documents do not provide sufficient information to predict the length of the line which may be affected. This could range from tens, to over a hundred kilometres in the most unfavourable circumstances.
4. The naturally unstable nature of discontinuous permafrost, with the tendency for aggradation or degradation in association with natural

microclimatic or climatic change is particularly important, but not discussed in the EIS.

5. Experience with the trans-Alaska oil pipeline, and the small diameter of the Norman Wells pipeline, indicate the technical feasibility of the project and the relatively small risk of oil spills. The lack of understanding of the problems and possible solutions relative to permafrost, however, involves an economic risk arising from eventual increased construction and maintenance costs. Maintaining a low risk of oil spills and reducing the extent of environmental damage (terrain disturbance) will depend on much greater attention to problems associated with permafrost than indicated in the EIS.
6. Pipeline designs for tributary river crossings are not yet completed sufficiently for environmental impact of the crossings to be assessed.
7. The oilfield expansion at Norman Wells with the construction of artificial islands with linking pipelines, is a complex engineering undertaking with implications for river hydrology. A number of inconsistencies appear between consultants' reports and the EIS. The incomplete nature of the designs and the uncertainties over the effects of constructions on the river regime make assessment of the environmental impact of the oilfield expansion difficult.

DOCUMENTS EXAMINED

Environmental Impact Statement:

(1) Vol. 1. Overview Summary. Norman Wells Oilfield Expansion and Pipeline Project.
Esso Resources Canada Ltd., Interprovincial Pipeline (NW) Ltd.
March 1980.

(2) Vol. 2. Oilfield Development. Norman Wells Oilfield Expansion.
Esso Resources Canada Ltd. March 1980.

(3) Vol. 3a. Norman Wells Pipeline Project.
Interprovincial Pipe Line Ltd. March 1980.

(4) Vol. 3b. Norman Wells Pipeline Project.
Interprovincial Pipe Line Ltd. March 1980.

(5) Vol. 3c. Norman Wells Pipeline Project.
Interprovincial Pipe Line Ltd. March 1980.

(6) Appendix I (Vol. 3-A) Norman Wells Pipeline Project.
Interprovincial Pipe Line (NW) Ltd.

Other Documents

(7) Geotechnical Investigation for Drilling Islands
EBA Engineering Consultants Limited. Sept. 1978.

(8) Design & Construction Plan for Development Islands at Norman Wells.
Beaver Dredging, Toronto. Undated.

(9) Regime of Mackenzie River at Norman Wells in Relation to Artificial Island Scheme.
Northwest Hydraulic Consultants Limited. Oct. 1979.

(10) Some Remarks Regarding Ice Jamming and the Design of Islands in the Mackenzie at Norman Wells.
Beaver Dredging, Toronto. Undated.

(11) Preliminary Design of a Pipeline System for Production Facilities at Norman Wells.
Northwest Hydraulics Consultants Limited. Dec. 1979.

(12) Preliminary Geotechnical Investigation for a River Crossing.
EBA Engineering Consultants Ltd. June 1979.

(13) Preliminary Environmental Impact Assessment
Norman Wells Development Plan.
Hardy Associates (1978) Ltd. Sept. 21, 1979 (Revd. Jan. 18, 1980)

(14) Height and Frequency of Ice Jamming on the Mackenzie River at Norman Wells, N.W.T.
Hardy Associates (1978) Ltd. Oct. 19, 1979.

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